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THE PROBLEM OF OBTAINING HIGH CONCENTRATIONS OF AEROSOLS

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/A Digest/

Aerosols are very important in the national economy, social hygiene, and national defense. Their basic properties (stability, coagulation, sedimentation, distillation, structure, form, density, size of their particles, electrical charge of the particles) depend on the nature of the smoke-forming agent, and therefore on the conditions under which the aerosol is formed.

Dispersion methods (atomization and explosion) (1-3) are more rarely used than the condensation methods (adiabatic expansion, evaporation, sublimation, chemical condensation, and electric arc). (4-17) All condensation methods require preliminary conversion of the mist-forming agent into the vapor phase, followed by controlled condensation of the vapor to attain particles of 10^{-5} centimeters.

Method of Preparing Aerosols of High Concentrations

All research on gas-dispersed systems described thus far in scientific literature has dealt with very small weight concentrations of the dispersed substance (that is, several milligrams per cubic meter). Important aerosols however, have a considerably greater concentration.

The water contained in one cubic meter of a cloud is usually 0.3 to 4.8, or sometimes as much as 8 grams. (18) Efforts of the author to prepare a more or less stable aerosol of greater concentration by various methods were unsuccessful, and for that reason a new method was tried:

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...ubstances with widely divergent boiling points, for example, glycerin (b p 29.. degrees) and liquid air (b p -194.4 degrees) or mercury (b p 357 degrees) and liquid nitrogen (b p -195.7 degrees), were used. The substance with the lower boiling point was poured onto the other, forming on the surface of the latter a large number of spheroidal droplets; with the evaporation of these droplets, an aerosol was created. This aerosol was formed mainly in the vapor space between the spheroids and the surface of the aerosol-forming liquid (or solid).

Preliminary heating of this mist-former increased its vapor pressure and consequently the concentration of the aerosol. Mercury at 250 degrees has a vapor tension of 74.375 millimeters, and with liquid air produces a mist with a concentration of 26 milligrams per liter; at 282 degrees, with a vapor pressure of 164.3 millimeters, the concentration produced is 37 milligrams per liter.

Pentane at room temperature (20 degrees) has a vapor tension of 420.2 millimeters and gives a very concentrated mist. Heptane and octane at 20 degrees (vapor tensions 35.5 and 10.45, respectively) give progressively lower, though still marked, concentrations. Homologues higher than octane in the series do not produce a noticeable mist at room temperature.

The concentration of the aerosol varies almost proportionately with the quantity of liquid air (or other substance) which forms the spheroids: 1.5 milliliter produces a mist with a concentration of 5.55 milligrams per liter; 3.0 milliliters, 12.1 milligrams per liter.

Detailed investigation of the whole process of forming aerosols by this method resulted in the following observations:

1. The mist-forming agent has a temperature lower than its boiling point. Next at its surface is a layer of an almost saturated vapor which is in equilibrium with the liquid agent. Therefore, the higher the temperature, the higher the vapor pressure, although the layer of vapor forms at any temperature.

2. As noted before, the liquid air forms spheroidal droplets (19-21). Between these and the heated surface of the mist-forming agent is the layer of vapor under low pressure which does not permit the liquid air and the liquid agent to touch each other. The process of the evaporation of the agent is thereby somewhat retarded.

Rebinder and Pleteneva (22) have shown that the temperature for the formation of the drops (T_s) is about 25 percent higher than the boiling point of the liquid--that is, about 100 degrees K for both liquid air and liquid nitrogen. They determined also that the vapor space between the drops and the liquid agent for water, methyl alcohol, and benzene is 87-90 μ. Gezekhus (19) gave a figure of 0.03-0.1 millimeters for water.

Deryagin and Prokhorov (23) established that the size of this vapor space depends on the vapor tension of the liquid, the temperature, and the degree of saturation by vapor of the space surrounding the drops. Thus, at 18 degrees the maximum width of the vapor space for hexane is 1,100 meters μ. For an agent with liquid air or liquid nitrogen, this space was calculated to be about 80-100 μ.

3. Depressions or small cavities are formed by the droplets of liquid air on the formerly mirrorlike surface of the mist-forming agent. This increases the contact surface of the liquid-air vapor and the saturated vapor layer of the other liquid.

4. The liquid air chills the saturated vapor layer of the other liquid, making it supersaturated and thus condensing it to form the aerosols in the vapor space between the liquid air and the other substance. In accordance with the

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Gibbs- ner theory the supersaturation during the process exceeds the critical degree of supersaturation 20 times. One centimeter of liquid air produces about 750 centimeters of air, and a high degree of dispersion is obtained.

Research on Electrical Properties of Aerosols To Explain the Mechanism of Mist-Formation

The electrical properties of aerosols depend on the methods of their formation. Dispersion methods and high temperatures tend to produce uncharged particles. Therefore, in order to classify the new method, the electrical properties of its particles were studied with ordinary ultramicroscopic equipment.

Light from a 500-watt kinolamp was directed through a condensor and then a radiation filter (which eliminated the heat rays), to be reflected from a mirror and through an objective into a cuvette. Particles of the aerosol in the cuvette were viewed between vertical electrodes 0.105 centimeter apart through a horizontal E. Leitz microscope with an objective and a 2.6 x 15-power ocular lens. In the latter a network of lines was spaced 0.01 centimeter apart for determining the rate of settling of the particles.

The cuvette was made of copper in order to keep the temperature uniform and to quickly eliminate convection currents (formed after the aerosols were let in). Leads with direct current and a voltage of 82 volts were attached to the electrodes. The apparatus was sensitive enough to detect particles bearing a charge of one electron.

Eventually the particles of all aerosols become charged for various reasons. That is why freshly made aerosols (prepared not more than 10 minutes previously) were used for these experiments. All surfaces which came in contact with the aerosol were greased with vaseline oil to insure greater accuracy.

Three aerosols were made using, first, oleic acid as a mist-forming agent and, secondly, with salol as the agent. With the oleic acid, 239, or 69.0 percent, of the particles were charged in the pulverization method; 49.7 percent were charged positively. The condensation method resulted in 478, or 21.9 percent, of the particles electrified, 49.5 percent positively. The liquid-air method closely approximated the latter with respect to the percentage of charged particles with 15.4 percent, or 424, charged, 44.5 percent positively.

With salol, pulverization of an alcohol solution resulted in 220, or 98.6 percent, electrified, 46.4 percent positively. Figures for the condensation method were 248 and 21.3 percent (38.7 percent positively); and for the liquid-air method, 682 and 12.8 percent (46.1 percent positively). Again, the liquid-air method more closely approximated the condensation method with respect to the percentage of charged particles.

The liquid-air method apparently is, for the most part, a condensation method.

The assumption that aerosols formed with liquefied gases and liquids with low boiling points are formed chiefly by condensation is valid, however, only insofar as the component with the low boiling point forms stable spheroids on the surface of the mist-forming agent and only insofar as the whole process proceeds smoothly.

Research on Oil Mists To Demonstrate the Duplicability of Aerosols Prepared by the New Method

Experiments were conducted with machine oil (d_{20}=0.914) and transformer oil (d_{20}=0.904), and the maximum variance in the weight concentration of the oil mists from experiment to experiment did not exceed 3-4 percent. Measurements of the relative optical densities of the aerosols related to time for three parallel experiments showed an over-all variation of 5-6 percent and an extreme divergence of about 10 percent for only three of the measurements taken.

Measurements plotted by Deryagin and Vlasenko (24) of the size of the particles with relation to time in three parallel experiments revealed an average variation of 5 percent and an extreme variation of 8 percent for only three of the 30 measurements. From these figures, the constants for the rates of coagulation were calculated according to Smolukhovskiy.

Measurements of weight concentrations and photometric and ultramicroscopic measurements completely confirm the duplicability of aerosols prepared by the new method.

Over 5,000 aerosols were made with the use of acetone, ethers, alcohols, fatty acids, salol, anthracene, water, and metals. Ethyl ether, pentane, ammonia, ethylene, liquid air, liquid nitrogen, and carbon dioxide were used as low-boiling agents in the preparation of the aerosols of these substances in making this study.

Conclusions

1. A new method is proposed for obtaining aerosols, based on the contact of two substances differing greatly in their boiling points so that the substance with the low boiling point is in a spheroidal state.

2. The new method is suitable for laboratory research because of its simplicity and applicability to a wide circle of substances and because it creates favorable conditions for forming highly dispersed, concentrated, and sufficiently stable aerosols.

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